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CULTIVAR

Registration of 'Pembroke 2016' Soft Red Winter Wheat

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Abstract

'Pembroke 2016' (Reg. No. CV-1144, PI 686941) is an early-maturing, semidwarf soft red winter wheat (*Triticum aestivum* L.) cultivar developed and released in 2016 by the Kentucky Agricultural Experiment Station for its combination of high yield potential, excellent test weight, resistance to lodging, and resistance to *Fusarium* head blight (FHB), a persistent threat in Kentucky because of the grain crop rotation most widely used by farmers. In the fall, the wheat crop is planted directly into corn (*Zea mays* L.) stubble that harbors the causal fungus for FHB, *Fusarium graminearum* Schwabe. Therefore, the main focus of our breeding program is the development of FHB-resistant winter wheat cultivars. The cross from which Pembroke 2016 was derived is 'Pioneer 25W33'/'Pioneer 25W60'//Pioneer 25W33/KY90C-042-37-1. The pedigree of KY90C-042-37-1 is 'LB 63'/'Freedom'. The cross was made in 2003, and Pembroke 2016 was initially selected from $F_{4:5}$ head rows in 2008 using a modified bulk breeding method. Breeder seed of Pembroke 2016, tested as KY03C-1002-02, comprised selected rows that carried the resistance allele at a major FHB resistance quantitative trait locus, *Fhb1*. Pembroke 2016 has been extensively tested in multilocation replicated breeding line yield trials, the Uniform Eastern Soft Red Winter Wheat Nursery in 2011 and 2012, and the Kentucky Wheat Variety Trial since 2012.

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The prevalent grain crop rotation in Kentucky consists of corn (*Zea mays* L.) planted in the spring, followed by wheat (*Triticum aestivum* L.) planted directly into corn stubble, followed by double-crop soybean [*Glycine max* (L.) Merr.]. Planting is done with little or no tillage, leaving abundant crop residue on the soil surface. *Fusarium* head blight (FHB) or head scab is a problematic disease of wheat and barley (*Hordeum vulgare* L.) worldwide; the grain crop rotation in Kentucky ensures that the Kentucky wheat crop is always at risk because the causal agent for this disease, *Fusarium graminearum* Schwabe, persists in corn residue. Development of resistant cultivars is a paramount strategy for reducing the impact of this disease (McMullen et al., 2012) and is thus the primary focus of the Kentucky Agricultural Experiment Station breeding program.

'Pembroke 2016' (Reg. No. CV-1144, PI 686941) is a soft red winter wheat developed and released in 2016 by the Kentucky Agricultural Experiment Station. Pembroke 2016 was released for its effective resistance to FHB, superior grain yield potential, and excellent test weight and lodging resistance. Pembroke 2016, tested as KY03C-1002-02, was developed from the cross 'Pioneer 25W33'/'Pioneer 25W60'//Pioneer 25W33/KY90C-042-37-1. The pedigree of KY90C-042-37-1 is 'LB 63'/'Freedom'. The source of the resistance alleles at the scab resistance quantitative trait locus (QTL) *Fhb1* is not clear from the pedigree of Pembroke 2016. Pembroke 2016 was named for the Pembroke silt loam soil series the prevalent soil series in the wheat-producing areas of Kentucky. Like Pembroke 2014 (Van Sanford et al., 2016), Pembroke 2016 is a cultivar sharing the Pembroke brand that has been chosen by the Kentucky Small Grain Growers' Association (https://www.kysmallgrains.org/); however, Pembroke 2016 is not related in any way to Pembroke 2014.

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Abbreviations: DON, deoxynivalenol; FDK, *Fusarium*-damaged kernels; FHB, *Fusarium* head blight; MAS, marker-assisted selection; QTL, quantitative trait locus.

Methods

Population and Line Development

The four-way cross from which Pembroke 2016 was derived was made in the greenhouse in Lexington, KY, in 2003. The F_1 of this cross was planted in a single row at Spindletop Farm (38.1304 N, 84.4913 W) in Lexington, where the soil type is a Maury silt loam (fine, mixed, semi active, mesic Typic Paleudalf). The row was harvested in bulk to produce F_2 seed, which was planted at the same location the following October. Individual heads were selected, collected in a bag, and threshed in bulk to provide seed for the F_3 population. The same procedure was followed to generate the F_4 population, after which individual F_4 heads were selected, threshed into headrow trays, and planted as $F_{4:5}$ headrows. Selected rows were harvested separately and planted as unreplicated $F_{4:6}$ preliminary trial entries in augmented design tests at Lexington and Schochoh, KY, in 2008.

Purification and Increase

$F_{6:7}$ headrows were grown in 2010 for purification and increase. Phenotypically selected rows were screened for the presence of the resistance alleles at the major scab resistance QTL, *Fhb1,* using data provided by the Eastern Regional Small Grains Genotyping Laboratory (http://www.ars.usda.gov/News/docs.htm?docid=19522). Seed from selected rows was bulked and increased in 2011–2012 at the University of Kentucky's Spindletop Farm. In fall 2013, seed was sent to Yuma, AZ, to be increased. Approximately 14.1 m^3 of seed was produced and distributed to three seed growers in Kentucky in fall 2014 for production of foundation seed of Pembroke 2016.

Statistical Analysis

SAS version 9.3 (SAS Institute, 2011) was used to perform statistical analyses. Analysis of variance was performed using a mixed model in which genotypes were fixed and environments and replications within environments were treated as random effects. Genotype means were compared with a least significant difference (LSD) test ($P = 0.05$).

FHB Screening

Pembroke 2016 has been evaluated for FHB resistance in a mist-irrigated, inoculated nursery at Lexington from 2012 to the present. *Fusarium graminearum* was cultured on corn kernels that served as grain spawn to inoculate the nursery and was applied in the scab nursery at the rate of 12 g m^{-2} (Agostinelli et al., 2012; Balut et al., 2013). Inoculum comprised 27 isolates taken from scabby wheat seed collected from 2007 to 2010 at multiple locations across Kentucky. Inoculum was spread in the rows of the scab nursery at Feekes growth stage 9 (Large, 1954) to ensure that spore production would be occurring when the wheat flowered. Scab ratings were recorded on a 0-to-9 scale at 21 to 24 d post-heading. On the rating scale, 0 represents <10% bleached spikelets within a plot and 9 signifies >90% of the spikelets in a given plot are symptomatic; this FHB rating scale is used by our breeding program and by some of the programs that participate in the Uniform Northern and Uniform Southern Scab Nurseries (https://scabusa.org/publications#pubs_uniform-reports). Detailed symptom readings included incidence (%), the proportion of 20 representative spikes that contained at least one bleached spikelet, and severity (%), the mean proportion of bleached spikelets of 10 symptomatic spikes. The FHB index (%) is defined as the product of incidence and severity divided by 100.

Grain samples from the scab nursery were processed as described previously to estimate *Fusarium*-damaged kernels (FDK; Agostinelli et al., 2012; Balut et al., 2013). The same samples were then sent for deoxynivalenol (DON) analysis at the University of Minnesota DON Testing Laboratory using gas chromatography with mass spectrometry (Mirocha et al., 1998; Fuentes et al., 2005).

Release Mechanism

Pembroke 2016 was released directly and licensed exclusively to the Kentucky Small Grain Growers' Association (http://www.kysmallgrains.org/), as was the case with Pembroke 2014 (Van Sanford et al., 2016). Plant variety protection was not applied for. Foundation class seed was sold to growers, who were then free to maintain their own seed supply or sell Pembroke 2016 in compliance with the Kentucky Seed Law.

Characteristics

Botanical Description

Pembroke 2016 exhibits erect growth habit at the juvenile stage. Plant color at GS 9 is green. The flag leaf of Pembroke 2016 at boot stage is erect, and the peduncle is free of waxy bloom. Glume color of Pembroke 2016 is white; glumes have a rounded shoulder and acuminate beak. The spike is fully awned, middense and tapering. Kernels are ovate with rounded cheeks, a shallow crease, and a midsize brush.

Agronomic Performance

We began testing Pembroke 2016 in multilocation replicated breeding line yield trials in Kentucky in 2009. Since 2012, Pembroke 2016 has been tested in the Kentucky Wheat Variety Trial (Table 1; Bruening et al., 2012). Cultural practices recommended for Kentucky wheat producers and described in Lee et al. (2009) were used in managing the breeding line and cultivar trials. Pembroke 2016 is an early-heading cultivar, approximately 1 d later than Pembroke 2014 (Van Sanford et al., 2016) and approximately 7 d earlier than 'Truman' (McKendry et al., 2005). Pembroke 2016 is short-statured, approximately 5 cm shorter than the average of all cultivars tested in the Kentucky Wheat Variety Trial from 2013 to 2016 (data not shown).

Pembroke 2016 has the insensitive alleles at the *Ppd-D1* photoperiod locus, based on DNA marker results, and thus begins to grow rapidly in late winter–early spring. We recommend to growers that Pembroke 2016 should be one of the last cultivars to be planted in the fall to minimize the risk of spring freeze damage. All marker data reported herein may be confirmed at https://www.ars.usda.gov/southeast-area/raleigh-nc/plant-science-research/docs/small-grains-genotyping-laboratory/regional-nursery-marker-reports/.

Pembroke 2016 had good straw strength, and its lodging resistance is good, although slightly less than that of Pembroke 2014. There was minimal lodging in the state variety test during the

Table 1. Agronomic performance of Pembroke 2016 and other soft red winter wheat cultivars in Kentucky. Yield mean based on 2013–2016 trials; other trait means from 2016 trial only.

Cultivar	Grain yield	Grain volume weight	Lodging	Height	Days to heading
	kg ha^{-1}	kg hL^{-1}	0–9†	cm	d after 1 Jan.
AgriMAXX 415	6025.4	75.0	0	36	116
BECK 120	6338.8	69.3	0	35	115
KAS S1200	6289.1	71.6	0	36	117
Pembroke 2008	5699.6	69.3	0	36	115
Pembroke 2014	5757.1	72.5	0	35	111
Pembroke 2016	6047.0	73.6	0	35	112
25R32	5821.2	73.9	0	38	114
26R10	6414.0	73.9	0	36	118
26R41	6194.9	72.4	0	36	117
PROGENY P 357	6131.7	73.3	0	37	116
PROGENY P 870	6191.5	69.1	0	35	117
SS 8340	6056.2	69.0	0	36	116
SS 8700	6073.9	74.5	0	39	116
SYNGENTA SY 007	5812.4	72.3	0	37	117
Truman	5578.7	71.6	0	41	112
Mean	6028.8	72.1	0	36.5	115.3
Location years	28	7	7	7	7
LSD (0.05)	497.7	2.5	0	2.2	2.0

† Lodging score: 0 = no lodging; 9 = completely lodged.

years Pembroke 2016 was tested such that lodging was reported only in 2013, 2014, and 2017 (University of Kentucky, 2017). In those respective years, lodging of Pembroke 2016 was 5, 1, and 7%, whereas lodging of Pembroke 2014 was 0, 0, and 3%. Based on DNA marker data, Pembroke 2016 carries the *Rht-B1b* allele for reduced height. When comparing yields of Pembroke 2016 and other scab-resistant cultivars in the 2011 to 2014 Kentucky wheat variety trials, Pembroke 2016 was similar to '25R32' but significantly higher yielding than Truman, which is frequently used as a scab resistant check in the eastern US wheat region (Table 1). Pembroke 2016 was entered in the Uniform Eastern Soft Red Winter Wheat Nursery and tested at 26 locations in 2011–2012 and 2012–2013 (USDA–ARS, 2016). In an analysis of those entries common to both years of the test, Pembroke 2016 had an average yield of 4909 kg ha^{-1}, not significantly different from yields of the checks Bess (PI 642794; 4580 kg ha^{-1}), 'Branson (4994 kg ha^{-1}), and MO080104 (4875 kg ha^{-1}), based on least squares means from data collected at 21 locations over 2 yr (Table 2).

Disease Resistance

Pembroke 2016 was extensively tested in our mist-irrigated FHB nursery under very heavy disease pressure. In the 2016 misted, inoculated nursery in Lexington, Pembroke 2016 was used repeatedly since it was a check in all of the breeding line trials and was also entered in the state variety trial (Table 3). The trend in the scab nursery that year was relatively low FDK levels and higher-than-expected DON levels. For example, the susceptible check '2555' (PI 532914) had a DON value of 36.9 ppm. On the basis of 22 observations, Pembroke 2016 had an

Table 2. Agronomic performance of Pembroke 2016 and other entries common to the 2012 and 2013 Uniform Eastern Soft Red Winter Wheat Nursery.

Entry	Grain yield	Grain volume weight	Days to heading	Plant height
	kg ha^{-1}	kg hL^{-1}	d after 1 Jan.	cm
ARS07-0525	4506	74.3	119.1	80.8
Bess	4581	74.7	118.7	88.6
Branson	4991	73.2	117.6	81.8
DAS1003	4322	73.4	123.5	97.5
Pembroke 2016	4909	74.1	116.7	79.2
MO080104	4875	76.0	117.8	87.9
NC08-23324	4379	75.1	116.6	78.5
OH08-180-48	5148	74.8	121.2	83.3
Pembroke 2014	4839	74.9	116.2	74.7
Shirley	4982	71.8	119.4	77.2
VA08MAS-369	4847	76.3	116.8	81.5
VA09W-73	4730	75.4	117.0	82.6
VA10W-21	4915	73.9	117.7	83.1
Mean	4430	69.1	109.8	76.9
LSD (0.05)	314.9	1.5	2.0	3.6

Table 3. *Fusarium*-damaged kernels (FDK) and deoxynivalenol (DON) concentrations in Pembroke 2016 and other scab nursery check cultivars, Lexington, KY, 2013–2016.†

Entry	FDK				DON			
	2013	2014	2015	2016	2013	2014	2015	2016
	%				ppm			
2555	58.0	30.7	–	22.3	28.0	20.3	–	36.9
Pembroke 2016	50.0	8.9	2.0	12.9	14.9	7.1	2.0	11.9
Pembroke 2014	30	10.0	1.3	11.7	12.8	7.7	1.5	11.3
Ernie	85	25.5	8.8	9.8	22.5	17.0	5.4	22.5
Truman	17.5	7.7	1.8	5.8	8.7	15.4	2.0	10.0
LSD (0.05)	2.1	1.5	1.0	1.6	1.8	1.8	1.1	1.9

† Data presented are entry means based on multiple observations in the inoculated, mist irrigated scab nursery, Lexington, KY, 2013–2016.

average FDK value of 12.9% versus 22.3% for 2555 and 5.8% for the resistant check, Truman. Pembroke 2016's DON concentration (11.9 ppm) was not significantly different from that of Pembroke 2014, but it was just significantly ($P < 0.05$) higher than that of Truman (10.0), which is a resistant check in the Uniform Northern Scab Nursery (http://www.scabusa.org). All of the 2016 scab nursery data can be found at University of Kentucky (2016). To put the data into context, the DON values in the 2016 scab nursery ranged from 3.0 to 52.2 ppm, with a mean of 18.4 (data not shown).

Pembroke 2016 was grown in the fungicide × variety trials at Spindletop Farm in 2014 and at both Spindletop Farm and the West Kentucky Research and Education Center at Princeton, KY, in 2016 (Tables 4 and 5, respectively). The tests included widely grown wheat cultivars and advanced breeding lines; for brevity, only cultivar data are shown. These plots were inoculated with 17.8 g m^{-2} grain spawn spread at the boot stage (Feekes 9). Prosaro (Bayer CropScience; prothioconazole {2-[2-(1-chlorocyclopropyl)-3-(2-chlorophenyl)-2-hydroxypropyl]-1,2-dihydro-3H 1,2,4-triazole-3-thione} and tebuconazole {α-[2-(4-chlorophenyl)ethyl]- α-(1,1-dimethylethyl)- 1H −1,2,4-triazole-1-ethanol}) were applied at anthesis (Feekes 10.5.1) at a rate of 0.475 L ha^{-1}, followed 24 h later with application of a conidial spray (100,000 spores mL^{-1} at a rate of 10 mL m^{-2}). Grain from these tests was harvested with a small plot combine and subsequently cleaned using sieving and low airflow similar to scab nursery grain sample processing. *Fusarium*-damaged kernel determination and sample preparation for DON analysis were as described previously (Agostinelli et al., 2012; Balut et al., 2013).

Pembroke 2016 is moderately resistant to powdery mildew [caused by *Erysiphe graminis* (DC.) f. sp. *tritici* Ém. Marchal; syn. *Blumeria graminis* (DC) E. O. Speer] and moderately resistant to prevalent races of stripe rust (*Puccinia striiformis* Westend.). Pembroke 2016 is moderately susceptible to speckled leaf blotch (caused by *Septoria tritici* Rob. in Desm.) and moderately resistant to leaf rust (caused by *Puccinia triticina* [= *P. recondita* Rob. ex Desm. f. sp. *tritici*]). The cultivar is susceptible

Table 4. *Fusarium* head blight symptoms of Pembroke 2016 and other soft red winter wheat cultivars with and without fungicide† treatment, Lexington, KY, 2016.

Cultivar	Control				Fungicide			
	DON	FDK	Index	Heading	DON	FDK	Index	Heading
	ppm	%	%	Julian	ppm	%	%	Julian
AgriMAXX 413	1.7	4.2	12.4	131.7	0.2	1.6	2.1	130.7
ARMOR HAVOC	1.7	3.6	8.6	128.7	0.4	0.7	1.8	128.7
BECK 120	2.7	4.0	5.5	129.7	0.4	1.8	2.3	129.0
Dyna-Gro 9171	2.4	3.5	7.5	129.3	0.3	2.4	1.7	129.3
Dyna-Gro 9223	2.1	3.8	11.2	132.0	0.5	1.3	2.9	131.0
KAS S1200	1.4	3.4	4.7	129.0	0.2	1.2	1.3	129.0
KAS S2000	1.0	2.8	11.4	129.0	0.3	1.2	2.6	128.7
Pembroke 2016	1.7	1.7	6.3	129.3	0.5	0.8	1.6	129.3
Pembroke 2008	2.1	2.9	8.8	131.0	0.7	1.1	3.6	131.0
Pembroke 2014	1.1	1.2	5.9	129.0	0.3	1.0	3.5	128.3
25R32	1.1	3.1	5.7	131.0	0.2	1.2	1.3	130.7
25R40	2.7	3.6	6.2	131.3	1.2	2.0	2.4	132.0
26R10	5.2	7.2	13.9	131.7	1.6	2.1	7.2	131.7
26R41	3.7	4.3	5.2	131.0	0.9	1.1	3.1	130.7
26R53	2.8	3.2	5.1	131.3	0.6	1.0	2.1	131.3
Syngenta SY483	6.7	6.7	17.3	132.0	2.4	2.6	5.5	132.0
Truman	0.4	1.1	13.9	137.7	0.1	0.5	6.6	137.3
USG 3438	2.5	6.0	3.2	130.0	0.4	0.6	0.6	130.0
Mean	2.1	3.3	7.8	130.9	0.6	1.2	3.1	130.7
LSD	1.6	1.9	6.3	0.8	0.4	0.8	2.5	0.8
CV	44.9	34.4	49.1	0.4	48.1	42.1	49.5	0.4

† Prosaro fungicide applied at Feekes growth stage 10.5.

Table 5. *Fusarium*-damaged kernels (FDK) and deoxynivalenol (DON) concentration of wheat varieties with and without fungicide treatment†, Lexington and Princeton, KY, 2014.

Entry	Lexington				Princeton			
	Control		Fungicide		Control		Fungicide	
	DON	FDK	DON	FDK	DON	FDK	DON	FDK
	ppm	%	ppm	%	ppm	%	ppm	%
ARMOR HAVOC	3.3	5.2	1.0	2.3	2.1	0.6	0.6	0.0
AgriMAXX 413	4.6	7.4	2.0	3.2	2.1	1.0	0.7	0.2
BECK 113	1.8	3.1	0.9	1.4	0.5	0.6	0.3	0.5
BECK 120	3.9	5.5	1.6	3.7	1.5	0.9	1.0	0.2
Dyna-Gro 9042	4.2	5.0	2.6	2.9	3.6	2.2	1.7	0.8
Pembroke 2016	1.5	2.6	1.5	1.4	0.9	0.4	0.6	0.2
Pembroke 2014	1.4	1.5	0.8	1.0	1.0	0.7	0.3	0.3
Pembroke 2008	5.0	5.8	2.4	3.4	2.2	0.8	1.3	0.4
25R32	2.0	3.1	0.6	1.6	0.5	0.6	0.3	0.2
25R40	4.6	4.4	2.4	3.1	3.9	0.9	2.3	0.3
26R10	4.6	5.3	2.4	3.3	4.1	1.4	2.2	0.7
26R53	3.5	4.8	1.7	2.5	3.9	0.9	1.7	0.0
SC 1321	4.1	7.1	1.8	3.7	1.6	0.4	0.9	0.5
SS 8700	4.9	7.3	2.0	3.0	2.8	1.5	2.2	0.3
SYNGENTA SY 483	5.0	4.4	1.0	1.8	6.4	2.4	2.7	0.9
Truman	2.9	2.8	0.2	0.9	3.1	1.1	1.1	0.5
Mean	3.6	4.4	1.5	2.3	2.5	1.0	1.2	0.4
LSD (0.05)	1.8	2.2	1.0	0.9	1.1	0.9	0.7	0.4

† Prosaro fungicide applied at Feekes growth stage 10.5.

to the prevalent races of stem rust (*P. graminis* Pers.:Pers. f. sp. *tritici* Eriks. & E. Henn.) for which it was screened at the seedling stage as an entry in the Uniform Eastern Soft Red Winter Wheat Nursery. Disease data from the 2012 harvest year of the Uniform Eastern Soft Red Winter Wheat Nursery are presented in Table 6. Only entries common to 2012 and 2013 are presented; the full data sets from both years can be downloaded at USDA–ARS (2016). Two-year foliar disease entry means from the 2016 and 2017 state variety trial are shown in Table 7.

Table 6. Disease reaction of Pembroke 2016 and other soft red winter wheat cultivars and breeding lines common to the 2012 and 2013 Uniform Eastern Soft Red Winter Wheat Nursery.†

Entry	Powdery mildew	Septoria leaf blotch	Stripe rust	Leaf rust
	0–9	0–9	0–9	0–9
ARS07-0525	2.0	4.3	1.5	1.4
Bess	2.4	3.7	2.4	4.9
Branson	1.0	3.0	1.6	3.8
DAS1003	0.8	2.1	4.1	5.3
Pembroke 2016	1.8	3.8	3.7	4.8
MO080104	0.9	4.0	1.7	4.3
NC08–23324	2.4	4.2	5.4	0.8
OH08-180-48	3.4	2.4	1.5	1.0
Pembroke 2014	0.6	4.1	2.1	5.3
Shirley	0.0	2.5	5.2	1.0
VA08MAS-369	1.0	2.2	1.0	1.6
VA09W-73	1.0	2.4	1.8	2.1
VA10W-21	2.1	3.0	6.8	3.3
Location mean	1.7	3.1	2.7	3.0

† Data presented from 2012 only, when most locations reported diseases on the same scale. Ratings for powdery mildew, Septoria leaf blotch, stripe rust and leaf rust are the average of all locations reporting on those diseases. 0 = no evidence of disease, 9 = ≥90% coverage of leaf surface.

Pembroke 2016 is also susceptible to prevalent biotypes of Hessian fly [*Mayetiola destructor* (Say)].

Milling and Baking Quality

Milling and baking quality of Pembroke 2016 was assessed at the USDA Soft Wheat Quality Laboratory in Wooster, OH (Table 8). In comparison to the other entries common to both 2012 and 2013, Pembroke 2016 had lower-than-average grain volume weight and grain protein concentration (AACC, 2000). Cookie diameter of Pembroke 2016 was lower than all

Table 7. Disease reaction of Pembroke 2016 and other soft red winter wheat cultivars and breeding lines grown in the 2016 and 2017 Kentucky wheat variety trials.†

Entry	Leaf rust	Leaf blotch	Powdery mildew
	0–9	0–9	0–9
Hilliard	1.0	3.4	1.4
USG 3197	1.3	5.8	5.1
BECK 125	1.3	4.8	4.8
26R41	1.8	5.3	3.7
Syngenta SY 547	2.0	3.1	2.0
USG 3895	2.0	5.5	4.9
AgriMAXX 463	2.8	4.7	5.3
Pembroke 2016	3.0	5.2	4.1
Pembroke 2014	5.4	5.8	2.1
26R53	3.5	5.2	5.2
AgriMAXX 444	3.6	4.8	5.6
Pembroke 2008	3.8	7.3	3.2
PROGENY P 243	3.8	3.7	5.3
AgriMAXX 446	3.9	5.3	6.2
Mean	3.4	5.1	4.8

† Ratings for leaf rust, leaf blotch, and powdery mildew are the average of all locations reporting those diseases. 0 = no evidence of disease, 9 = ≥90% coverage of leaf surface.

Table 8. Grain quality traits of Pembroke 2016 and other cultivars and breeding lines common to both the 2012 and 2013 Uniform Eastern Soft Red Winter Wheat Nurseries.

Entry	Grain volume weight	Whole grain protein	Whole grain hardness	Flour yield	Softness equivalent	Flour protein	Lactic acid SRC†	Sucrose SRC†	Cookie diameter
	kg hL^{-1}	g kg^{-1}	0–100	%	%	g kg^{-1}	%	%	cm
Branson	78.0	106.1	27.2	70.0	57.1	83.1	117.6	98.3	18.0
Bess	78.5	103.6	27.3	67.7	49.6	85.3	97.8	103.5	17.9
Shirley	77.6	110.6	28.8	69.9	51.6	85.9	96.3	96.4	18.5
MO080104	79.7	104.1	33.0	66.9	53.6	83.0	121.5	107.6	17.6
NC08-23324	79.6	104.8	36.0	67.7	48.5	86.3	113.3	103.6	17.8
Pembroke 2014	78.8	111.6	31.0	66.7	51.2	88.6	123.7	105.8	17.8
Pembroke 2016	78.6	84.7	39.8	70.4	47.4	89.0	112.4	105.3	17.7
VA08MAS-369	80.7	106.6	34.5	69.5	49.8	87.1	127.9	97.9	17.9
VA09W-73	79.9	106.4	37.4	68.1	53.1	82.7	108.4	93.8	18.2
VA10W-21	79.4	93.5	35.1	69.6	42.2	76.6	117.5	110.1	15.8
DAS1003	78.2	95.9	27.8	69.3	55.3	72.4	81.5	91.7	18.4
OH08–180–48	79.2	98.1	32.6	70.3	57.0	77.4	118.6	96.5	18.5
ARS07-0525	78.1	114.0	31.7	70.1	50.8	88.6	93.1	104.1	17.9
Mean	78.7	105.9	31.8	68.9	52.0	84.6	106.4	98.9	18.0

† SRC, solvent retention capacity. Data provided by USDA-ARS Soft Wheat Quality Laboratory, Wooster, OH.

entries except check cultivar MO080104 (17.7 vs. 17.6 cm). Flour yield of Pembroke 2016 was higher than any of the entries shown in Table 8. Lactic acid retention capacity, a predictor of gluten strength, was higher than average but close to the median value. Statistical significance of these comparisons could not be assessed from the data provided by the quality laboratory. Based on marker data, Pembroke 2016 does not carry the 1RS translocation and has 2+12 high molecular weight glutenin subunits.

Availability

Breeder seed of Pembroke 2016 will be maintained by the University of Kentucky wheat breeding project; small quantities may be obtained from the corresponding author. Seed of Pembroke 2016 has been deposited at the USDA–ARS National Plant Germplasm System, where it will be available upon publication.

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